

COMPARISON OF THE EARLY PERMIAN VERTEBRATE FAUNAS OF THE FOUR CORNERS REGION AND NORTH-CENTRAL TEXAS¹

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ABSTRACT: It has been thought for a long time that the differences between the Early Permian vertebrate faunas of north-central Texas and north-central New Mexico were due to the presence of a water barrier between these areas. New finds of vertebrates in southeastern Utah, in particular the discovery in this area of *Ectosteorhachis*, *Diplocaulus*, *Seymouria*, and most recently, the long-spined pelycosaur *Dimetrodon*, cast doubt on the long-term effectiveness of any such barrier. The presence of these animals in southeastern Utah indicates special resemblance of this fauna to that of north-central Texas. It is suggested that this resemblance is due to environmental similarity; both north-central Texas and southeastern Utah were deltaic regions in Early Permian time, near the borders of persistent seaways. The absence of these forms in the intervening areas of north-central New Mexico and southwestern Colorado may be accounted for by the apparently more "upland" conditions of these areas in Early Permian time. The special ways in which all the Four Corners faunas (southeastern Utah, southwestern Colorado, and north-central New Mexico) resemble one another, for examples, in the common possession of *Platyhystrix* and, in Utah and New Mexico, *Sphenacodon*, are thought to be due to geographic proximity.

INTRODUCTION

The best known Early Permian vertebrate fauna is that of the famous redbeds of north-central Texas, summarized by Romer (1958). Also well known is the contemporaneous fauna from north-central New Mexico, discussed by Langston (1953). The most recent general comparison of these faunas is by Romer (1960). Lately, Lower Permian strata farther west have begun to yield a varied assemblage of vertebrate fossils, in southeastern Utah (Vaughn, 1962, 1964a, 1965) and southwestern Colorado (Lewis and Vaughn, 1965). These later finds have not only shown the existence of genera and species previously unknown, but, in their demonstration of the basic similarity of Early Permian vertebrate faunas from widely separated areas, they allow new insight into particular paleozoogeographic phenomena. The general similarity of the continental vertebrate faunas of this horizon in Europe and North America has been discussed by Lewis and Vaughn (1965). This paper will treat of similarity—and difference—on a more local scale: between the region

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of north-central Texas and the region of the Four Corners (where Utah, Colorado, New Mexico, and Arizona meet).

It has been recognized for a long time that there are significant differences between the Early Permian vertebrate faunas of north-central Texas and north-central New Mexico. As Romer (1960:52-53) has summarized it: "Texas . . . and New Mexico faunas differ in part in the rarity or absence in the latter of many water-dwelling types; each has a few characteristic forms absent in the other area; both share a number of common and familiar genera, although it is probable that the species are different; differences in the case of a number of rare types may be due to accidents of collecting. The general picture is one of two essentially contemporaneous faunas, evolving along similar lines but differing in a fashion to be expected of continental assemblages separated from one another by such a broad water barrier as is known to have been present in eastern New Mexico and western Texas in early Permian times." Among the forms commonly found in Texas but never in New Mexico are: the crossopterygian fish *Ectosteorhachis*, the neotridian amphibian *Diplocaulus*, the advanced labyrinthodont amphibian *Seymouria*, and the distinctively long-spined pelycosaurian reptile *Dimetrodon*. *Dimetrodon*, as Romer (1960:52) has remarked, is the most dramatic example: "*Dimetrodon* is the most abundant form in every Texas horizon. . . ." The New Mexico pelycosaur phylogenetically closest to *Dimetrodon* is *Sphenacodon*, "definitely distinct generically but indistinguishable except for spine development"; the neural spines in *Sphenacodon* are much lower, nearer to the proportions of what was apparently normal for pelycosaurs.

Somewhat farther west, however, some of the animals common in Texas but absent from New Mexico have been found in the Cutler sediments of southeastern Utah. Already reported are *Ectosteorhachis* (Vaughn, 1962), *Diplocaulus* (Vaughn, 1965), and *Seymouria* (Vaughn, 1966). In addition, some of the elements rarer in Texas but totally unknown from New Mexico have now also been reported from farther west: the pelycosaur *Ctenospondylus* from southeastern Utah (Vaughn, 1964a) and the pelycosaur *Mycterosaurus* from southwestern Colorado (Lewis and Vaughn, 1965). These finds, and others to be noted below, tend to cast doubt on the long-term effectiveness of any water barrier that may have existed between the Midcontinent and the Four Corners. This doubt is intensified by the fact that *Dimetrodon* is now known from southeastern Utah.

Some new explanation of Early Permian vertebrate distributions in the western United States seems to be required. The answer would still seem to lie in paleogeography, but with the additional consideration of newly uncovered facts, and with attention to environmental dissimilarities. I think it is probable that the faunas from southeastern Utah and north-central Texas resemble one another because they lived in similar, deltaic environments, and that they differ from the intervening New Mexico fauna because the latter lived in a non-deltaic area; that is, that the differences between the Texas and

the New Mexico faunas are not due to the presence of any broad barrier to faunal distribution.

Throughout this discussion, reference will be made to Figure 1. In this map, simplified outlines of major Wolfcampian (early Early Permian) and early Leonardian (later Early Permian) paleogeographic features have been superimposed onto outlines of parts of the states in the region. The positions and extents of the positive areas, or "highlands," have been compiled from a number of sources, cited in the caption. The outlines of the "seaways" will

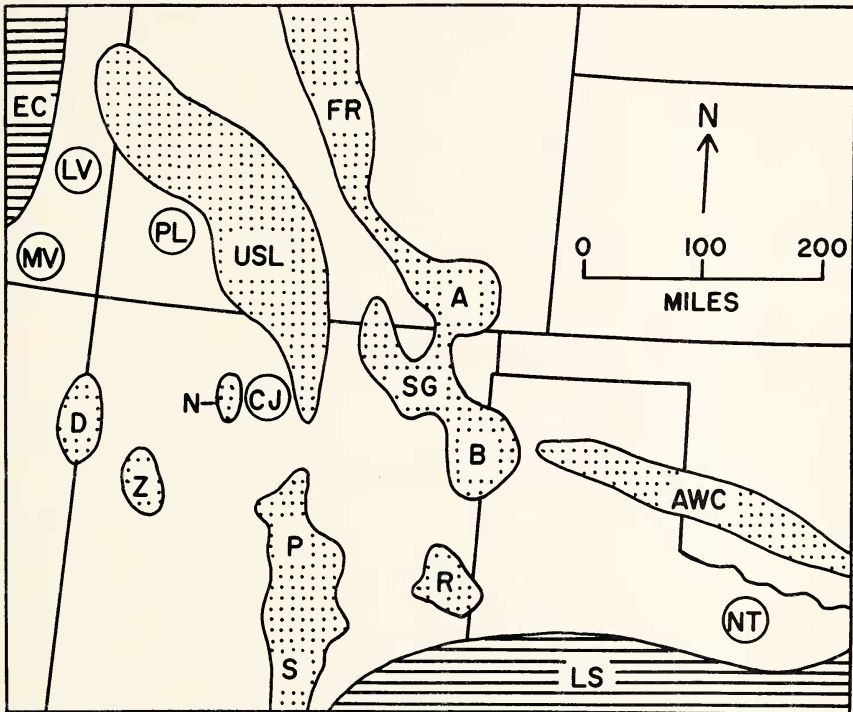


Figure 1. Simplified map of Wolfcampian and early Leonardian vertebrate faunas, highlands, and seaways, in the region from the Four Corners to the Midcontinent. Faunas indicated by circles: CJ, Coyote-Jemez, in north-central New Mexico; LV, Lisbon Valley, and MV, Monument Valley, in southeastern Utah; NT, North-central Texas; and PL, Placerville, in southwestern Colorado. Highlands indicated by stipple: A, Apishapa; AWC, Amarillo-Wichita-Criner Hills; B, Bravo; D, Defiance; FR, Front Range; N, Nacimiento; P, Pederal; R, Roosevelt; S, Sacramento; SG, Sierra Grande; USL, Uncompahgre-San Luis; Z, Zuni. Seaways indicated by horizontal ruling: LS, "Leonardian" seaway with approximate northern boundary—subject to much fluctuation; EC, seaway represented by Elephant Canyon Formation. Paleogeographic features compiled from maps and data published by: Baars, 1962; Hills, 1963; King, 1959; and Rascoe, 1962.

receive special comment further on. The Wolfcampian and early Leonardian faunas are indicated by encircled letters: "LV" and "MV" stand, respectively, for the faunas known from the undifferentiated Cutler Formation of Lisbon Valley and from the Cutler Group of Monument Valley, both of these in San Juan County, southeastern Utah; "PL" stands for the fauna known from the Cutler Formation near Placerville, San Miguel County, southwestern Colorado; "CJ" stands for the faunas known from the Cutler and Abo Formations in and about Coyote, Rio Arriba County, and Jemez Springs, Sandoval County, north-central New Mexico; and "NT" stands for the fauna known from the Wichita Group of north-central Texas. Only the Wolfcampian and early Leonardian vertebrates from Texas are emphasized; the fauna from the higher Clear Fork Group of Texas is of later Leonardian horizon, younger than the Four Corners faunas, and will not be considered except incidentally—although there are no animals known from the Clear Fork Group that would contradict the explanations developed here. For stratigraphic correlations of these faunas, see Dunbar, *et al.* (1960), Langston (1953), Lewis and Vaughn (1965), Romer (1960), and Vaughn (1962, 1964a, 1965).

Dimetrodon IN SOUTHEASTERN UTAH

In 1960, when I first undertook collection of vertebrate fossils from the Cutler sediments of southeastern Utah, I expected that no trace of *Dimetrodon* would be found, because of my conviction at the time that there was an effective Early Permian water barrier between the Four Corners and Texas. But when, in addition to elements commonly found in both New Mexico and Texas, good signs of *Ectosteorhachis*, *Diplocaulus*, and *Seymouria* were recovered, I began to see the basic similarity of the Utah fauna to that of Texas; and a detailed re-examination, including further preparation, of all fragmentary materials collected during past field seasons was made in a search for *Dimetrodon*. This search was rewarded by the finds of parts of characteristic neural spines referable to *Dimetrodon* from six different localities low in the Organ Rock Shale, a formation equivalent to some horizon in the upper part of the Wichita Group of Texas, earliest Leonardian in age (see Vaughn, 1964a).

The first find was embarrassing. In my report on the vertebrates of the Organ Rock Shale (Vaughn, 1964a), I described materials of *Ctenospondylus* aff. *C. casei*, a pelycosaur with fairly long, laterally flattened neural spines known theretofore only from a single specimen from the upper Wichita Group of Texas. The Organ Rock Shale had yielded a good number of specimens, including a skull and associated postcranial parts from one quarry. Among materials from other quarries that I thought were referable to *Ctenospondylus*, I noted NTM VP 1018, a badly weathered string of three dorsal vertebrae with partial neural spines, found near the base of the northern slope of Hoskinnini Mesa in Monument Valley, in NW¼ sec. 8, T. 43 S., R. 14 E., San Juan

County, Utah.³ It is now obvious that this identification was incorrect. Large parts of the neural spines of two of the vertebrae are preserved, but about 70 mm. above the bases of the spines, the preservation is in impression only, with the impression of only one of the spines completely bordered fore and aft. I had thought that this rounded impression represented the posterior edge of a distorted *Ctenospondylus* spine. Now, after re-examination with the aid of a rubber mould of the impression, it is clear that what is really represented is somewhat more than a lateral half of a subcircular spine complete with the deep, longitudinal fore and aft grooves so characteristic of most species of *Dimetrodon* (see Romer and Price, 1940). These grooves can be followed onto the proximal part of the spine where, on the anterior surface, a thin, longitudinal ridge appears within the groove—again as in *Dimetrodon*. The lateral surfaces of the proximal portion of the spine are flattened, and the distal, rounded surfaces are marked by longitudinal striae; these features are also in complete accord with the pattern of *Dimetrodon*. The centra, badly weathered, are about 37 mm. long and about 29 mm. high at their ends. These dimensions are very close to those of a posterior dorsal vertebra of *Dimetrodon limbatus* from the upper part of the Texas Wichita Group (Romer and Price, 1940: table 3), but in the absence of better materials and in view of the distance between Utah and Texas, it seems wise not to attempt specific identification at this time. The impressions of the two spines are incomplete distally: the total length of each of the spines as preserved, including the basal bony part and the distal impression, is about 180 mm. The better of the two impressions shows that the subcircular part of the spine, about 140 mm. above the base, had a transverse diameter of about 12 mm. The natural cast of the neural canal shows that the floor of the canal was well ossified, as in sphenacodontid pelycosaurs generally. The spines have been compared with vertebrae of species of *Dimetrodon* on hand from both the Wichita and Clear Fork Groups of Texas, and I am satisfied that NTM VP 1018 represents that genus.

Subsequently, more parts of neural spines referable to *Dimetrodon* were turned up in collections from the Organ Rock Shale. These are catalogued as: UCLA VP 1675, collected by J. R. Dyer in 1950 about 2 miles east of Mitchell Butte in the Arizona part of Monument Valley; NTM VP 1039 from NE $\frac{1}{4}$ sec. 11, T. 43 S., R. 15 E., NTM VP 1040 and 1042 from SW $\frac{1}{4}$ sec. 12, T. 43 S., R. 16 E., NTM VP 1041 from about 2 miles southeast of Monument Pass in approximately the southern part of sec. 17, T. 43 S., R. 17 E., and NTM VP 1043 from NW $\frac{1}{4}$ sec. 18, T. 43 S., R. 17 E., San Juan County, Utah. Most of these catalogue numbers designate more than only one fragment of spine. UCLA VP 1675 includes two fragments that show the characteristic transition from a compressed, laterally flattened proximal portion to

³The abbreviations "NTM" and "UCLA" stand for the collections of, respectively, the Navajo Tribal Museum, Window Rock, Arizona, and the University of California, Los Angeles.

a swollen, transversely widened distal portion. All lots include fragments that show the dumb-bell or figure-8-shaped cross-section of the distal part, compressed from front to back, wide from side to side, and with deep fore and aft grooves. The transverse diameters of the distal fragments range from about 8 to about 13 mm.

It would, of course, be desirable to be able to identify positively parts of *Dimetrodon* other than neural spines from the Organ Rock Shale. Even partially articulated skeletons are, however, rarely found in this formation, and the difficulty in distinction of isolated skeletal elements, other than spines, of the three sphenacodontine pelycosaurs *Sphenacodon*, *Ctenospondylus*, and *Dimetrodon* has been commented on by several authors (see Vaughn, 1964a). For the present, it is not possible to cite more than the given six occurrences of *Dimetrodon* in the Organ Rock Shale, but it may be pointed out that this record is greater than the one occurrence apiece that has established the presence of the pelycosaurian genera *Eothyris* and *Ctenospondylus* in the Wichita sediments of Texas (Romer and Price, 1940).

SIMILARITY OF THE EARLY PERMIAN ENVIRONMENTS AND FAUNAS OF SOUTHEASTERN UTAH AND NORTH-CENTRAL TEXAS

The Cutler Group in Monument Valley in southeastern Utah is divided into, in ascending order: Halgaito Shale, Cedar Mesa Sandstone, Organ Rock Shale, and De Chelly Sandstone (see Baars, 1962). The Halgaito Shale and Organ Rock Shale are redbeds, lithologically continuous to the East with arkosic sediments of the undifferentiated Cutler Formation derived through erosion of the Early Permian Uncompahgre-San Luis highland of southwestern Colorado (see Fig. 1). The intervening Cedar Mesa Sandstone is apparently principally of shallow-water marine origin; and the uppermost unit, the De Chelly Sandstone, seems to be of aeolian origin in this area although its south-eastward extension, the Meseta Blanca Sandstone, may represent marine conditions (Baars, 1962). Vertebrate faunas indicate a Wolfcampian age for the Halgaito Shale, equivalent to the lower part of the Texas Wichita Group, and a very early Leonardian age for the Organ Rock Shale, equivalent to the upper part of the Wichita Group (Vaughn, 1962, 1964a). The De Chelly Sandstone seems to be of early Leonardian age (Baars, 1962). The Halgaito Shale interfingers toward the Northwest with Wolfcampian marine carbonates of the Elephant Canyon Formation (Baars, 1962). This transition has recently been examined by the author in the region of Comb Wash, and the picture is one of genuinely deltaic conditions, with fossils in the Elephant Canyon facies that would seem to represent animals washed northwestward from the Halgaito delta. This corresponds with my earlier observation (Vaughn, 1962) that Halgaito drainage was, in general, toward the North. As Baars (1962:169) interprets it, "The depositional site of the Halgaito was probably a broad marginal marine mud flat, alternatively receiving fluvial

sedimentation and periodic marine invasions." The Elephant Canyon beds have also produced many marine invertebrates and remains of an actinopterygian fish remarkably advanced for its time; these, and other details, will be published later. The Organ Rock Shale thins northwestward to a pinch-out between the Cedar Mesa Sandstone and the White Rim Sandstone—a De Chelly equivalent. The Organ Rock, too, would seem to represent deltaic conditions; as Baars (1962:187) says, "the wide distribution and uniformity of the unit along with its proximity to the probably marine Cedar Mesa Sandstone suggest that deposition was on a broad coastal plain. It is possible that fluvial deposits were partly reworked by marine waters to provide the uniform distribution of the beds." These considerations provide the basis for the outline of the seaway northwest of Monument Valley presented in Figure 1. The outline is drawn to correspond with the approximate zone of facies change between, on the one hand, the Halgaito Shale of Monument Valley and the undifferentiated Cutler sediments of the general region of Lisbon Valley, and, on the other hand, the Elephant Canyon Formation—as this transition is understood from Baars' map (1962: fig. 9) and data and from my investigations currently underway. The same outline will serve for Organ Rock time, as may be seen in an examination of the fence diagram presented by Baars (1962: fig. 13). In summary, the region of Monument Valley would seem to have been deltaic in Halgaito time, covered by shallow marine water in Cedar Mesa time, and deltaic again in Organ Rock time. Later, in De Chelly time, conditions changed more drastically, with deposition of sand dunes, on the slopes of which are recorded only the trackways of tetrapods (see Vaughn, 1963b).

Romer (1958:165) has described the Early Permian paleogeography of north-central Texas, and we may draw from his observations: "in the later Carboniferous much of Texas was occupied by shallow seas. . . . To the south, marine conditions persisted through Wichita time, but in the collecting area the deposits of the Cisco, highest of definitely Carboniferous groups, indicate a trend toward continental conditions . . . [In the lowest part of the Wichita Group] limestones and marine shales disappear and continental conditions dominate, to continue with little interruption throughout the Permian exposures in northern Texas; during most of Wichita time the present line of the Salt Fork of the Brazos River roughly marks the boundary between marine beds to the south and continental sediments which extend northward across Oklahoma. The Wichita continental . . . sediments . . . are presumed to come from an emergent land mass to the east and a mountain chain to the north in (modern) Oklahoma. . . . The Texas collecting area appears to have been a broad deltaic region." The highland north of the delta is drawn in much simplified form in Figure 1, without attention to its subdivisions. The seaway to the South, sometimes referred to as the "Leonardian seaway," was of variable extent and occasionally transgressed far northward, as during the deposition of the Lueders Formation—a formation variously assigned to the top of the

Wichita Group (Dunbar, *et al.*, 1960) or to the base of the Clear Fork Group (Romer, 1958). The simplified boundary of this seaway presented in Figure 1 is intended only to outline approximately the more persistently marine part of its basin, to illustrate the essentially deltaic nature of the north-central Texas area during Wichita time.

Lists are available of the vertebrates known from the Halgaito Shale (Vaughn, 1962), Organ Rock Shale (Vaughn, 1964a), and the Wichita Group (Romer, 1958, 1960). These lists will not be repeated here; suffice it to say that the known faunas, including such familiar genera as *Xenacanthus*, *Eryops*, *Diadectes*, and *Ophiacodon*, demonstrate general similarity and permit approximate stratigraphic correlation. I shall confine myself for the most part to the significant ways in which the faunas of southeastern Utah and north-central Texas resemble one another, and to the ways in which these faunas differ from those of north-central New Mexico and southwestern Colorado. I shall also limit myself to discussion at the generic level, because of the frequent difficulty of comparison of species between widely separated areas at this horizon.

The crossopterygian fish *Ectosteorhachis* is known from the Halgaito Shale (Vaughn, 1962), and also from equivalent strata low in the undifferentiated Cutler sediments of Lisbon Valley about twelve miles south-southeast of the town of La Sal, San Juan County, Utah (Vaughn, 1965). In Figure 1, it may be seen that the Lisbon Valley area is also to be included as part of the deltaic region bordering the "Elephant Canyon seaway." The correlation between the Halgaito Shale and the lower Cutler strata in Lisbon Valley is now strengthened by recent discoveries of the rhachitomous amphibian *Platyhystrix rugosus* (UCLA VP 1677) in Lisbon Valley—previously known from the Halgaito—and the pelycosaur *Edaphosaurus novomexicanus* (UCLA VP 1676) in the Halgaito—previously known from Lisbon Valley. Further, small toothplates of a lungfish similar to *Gnathorhiza* are now known from both places (Halgaito: UCLA VP 1680; Lisbon Valley: UCLA VP 1678), as are also vertebrae of aistopod amphibians (Halgaito: UCLA VP 1681; Lisbon Valley: UCLA VP 1679). Although this is the first published report of actual parts of Early Permian lungfishes west of Texas, their presence in northern New Mexico has been suspected on the basis of fossilized burrows in the Sangre de Cristo Formation (Vaughn, 1964b), similar to burrows of *Gnathorhiza* in Texas (Romer and Olson, 1954). Although aistopods are unknown from New Mexico and Colorado, the lack of record may well be due to sampling error; the record of these very small animals in the Midcontinent is extremely scanty (see Baird, 1964). Probably not to be accounted for by sampling error is the absence of *Ectosteorhachis* in Colorado and New Mexico. Specimens of this fish are common in the Halgaito Shale, lower Lisbon Valley Cutler, and the Wichita Group, and this would seem to constitute a special resemblance between the faunas of southeastern Utah and north-central Texas. It may be noted here that in Utah *Ectosteorhachis* is not found above the Halgaito,

whereas in Texas this genus is known from higher levels in the Wichita. This may be part of a general picture of somewhat earlier onset of drier conditions in Utah than in Texas, a phenomenon indicated by both fauna and flora (Vaughn, 1964a), and corroborated by the earlier appearance of lungfish of *Gnathorhiza* type in Utah; in Texas, the lungfish of the Wichita Group is the apparently non-aestivating *Sagenodus*, replaced in the Clear Fork by *Gnathorhiza* (Romer, 1958).

The nectridian amphibian *Diplocaulus* is known from both the Wichita and Clear Fork Groups of Texas although it is rare in the former (Romer, 1958), and it is also known from the Halgaito equivalent in Lisbon Valley (Vaughn, 1965) where recent field work has uncovered a fairly large number of specimens. *Diplocaulus* is not known from southwestern Colorado, but there has been only one published report of Early Permian vertebrates from there (Lewis and Vaughn, 1965). Its absence from north-central New Mexico would seem to be genuine, in view of the long history of collection in that area (see Romer, 1960).

The well known genus *Seymouria*, an animal seemingly near the phylogenetic borderline between the labyrinthodont amphibians and the reptiles, is known from both the upper part of the Wichita Group and the lower part of the Clear Fork Group of Texas, and it has recently been reported from the Organ Rock Shale of the Cutler Group in Monument Valley (Vaughn, 1966). Like *Ectosteorhachis* and *Diplocaulus*, this genus is totally unknown from the well searched Lower Permian beds of north-central New Mexico. There is a seymouriid, not *Seymouria* itself, known from a single vertebra found in the undifferentiated Cutler Formation of southwestern Colorado (Lewis and Vaughn, 1965), and perhaps this indicates some degree of special similarity of Early Permian conditions in southwestern Colorado to the deltaic conditions in southeastern Utah—Figure 1 shows that the Colorado area lay considerably closer to the boundary of the "Elephant Canyon seaway" than did the New Mexico area. It may also be noted that the Colorado seymouriid, from a Wolfcampian horizon, seems to be more primitive than *Seymouria*. *Seymouria* is not known in Utah below the Organ Rock Shale, of earliest Leonardian age. Perhaps this indicates a movement of some faunal elements from the somewhat more upland area of southwestern Colorado into the region of southeastern Utah. This would resemble the apparent replenishment of faunal elements in north-central Texas from Oklahoma (see Olson, 1962).

The presence of *Dimetrodon* in the Organ Rock Shale as well as in the Texas Wichita Group, and its absence from southwestern Colorado and north-central New Mexico have already been noted, but it may be re-emphasized that the discovery of this pelycosaur in Utah removes the most dramatic of cited examples of Early Permian faunal differences between the Four Corners and the Midcontinent. Also, we now know that the three closely similar sphenacodontine pelycosaur *Dimetrodon*, *Ctenospondylus*, and *Sphenacodon* all lived together in at least one region. *Ctenospondylus* is known from good

specimens from the Organ Rock Shale, and although the definitely determinable Organ Rock materials of *Sphenacodon* are scanty (Vaughn, 1964a), this genus is also known from strata approximately equivalent to the Organ Rock in Lisbon Valley. The discovery of cranial and appendicular elements of a large sphenacodontid at this level in Lisbon Valley has already been published (Vaughn, 1965), and additional materials more recently collected from the same locality—including excellently preserved vertebrae in the UCLA collections—help show that this animal is closely comparable to *Sphenacodon ferocior* Romer, although the neural spines are proportionately slightly longer in the Utah form. Lest an old theory be revived that the difference between *Dimetrodon* and *Sphenacodon* merely represents sexual dimorphism, let it be remembered that *Sphenacodon* remains unknown from Texas, and in this connection, it may be pointed out that the difference of *Ctenospondylus* from both of these genera lies in more features than only the structure of the neural spines (Vaughn, 1964a).

The total known fauna of the Cutler sediments in southeastern Utah, including the recently discovered lungfish, helps demonstrate the general similarity of all Early Permian vertebrate faunas—at least those that lived in basins of continental deposition. But, the presence of *Ectosteorhachis*, *Diplocaulus*, *Seymouria*, and *Dimetrodon* in the Lower Permian of southeastern Utah, and the absence of these forms in north-central New Mexico and probably southwestern Colorado too, would seem to constitute special resemblance of the Utah fauna to that of north-central Texas, and perhaps the presence of *Ctenospondylus* in both these areas may be cited as additional evidence of similarity. There remain, however, differences between the Utah and Texas faunas. In part, these differences reflect uniqueness; as illustration, the seymouriamorph-diadectomorph intermediate *Tseajaia* (Vaughn, 1964a) is known from the Organ Rock Shale and from nowhere else. For the rest, the differences lie in special resemblances of the Utah fauna to that of north-central New Mexico, as illustrated by the record of *Platyhystrix* in the Halgaito Shale and its Lisbon Valley equivalent, a genus of limnoscelid cotylosaurs in the Halgaito Shale (Vaughn, 1962), and *Sphenacodon* in the Organ Rock Shale and its Lisbon Valley equivalent. *Platyhystrix* and a limnoscelid are also known from the Lower Permian of southwestern Colorado (Lewis and Vaughn, 1965).

The Early Permian vertebrate faunas of north-central New Mexico and southwestern Colorado are alike in most respects, including the absence of *Ectosteorhachis*, *Diplocaulus*, *Seymouria*, and *Dimetrodon*, but each also has its own characteristics. For examples, the rhachitinous amphibian *Chenoprosopus* is known only from New Mexico where it has been found at two separate localities (Vaughn, 1963a), and the haptodontine pelycosaur *Cutleria* is known only from Colorado (Lewis and Vaughn, 1965). The presence of the nitosaurid pelycosaur *Mycterosaurus* in southwestern Colorado is interesting inasmuch as this genus is known otherwise only from Texas. Perhaps this, like the Colorado seymouriid already noted, is a consequence of the

relative proximity of the Colorado area to the delta of southeastern Utah, but the picture is still far from clear.

HYPOTHESIS

That faunas from widely separated areas should each show special characteristics is to be expected, and it is also to be expected that the degree of propinquity should at least roughly affect faunal resemblance. In this way, the Early Permian vertebrate faunas from the several Four Corners areas (southeastern Utah, southwestern Colorado, and north-central New Mexico) not only each contain unique elements but also show special resemblance to one another—in the common possession of *Platyhystrix* and, in Utah and New Mexico, *Sphenacodon*. That these two elements are not known from Texas may be due to geographic distance and, possibly, some other obstacle to distribution. What this barrier (or perhaps better, “filter”) may have been is not clear, but it does now seem clear that any water barrier that may have existed could not have been very effective throughout the time involved.

The similarity of the Utah, Colorado, and New Mexico faunas is thus interpreted as possibly due to geographic proximity, but the special resemblance of the Utah fauna to that of Texas is probably due to a different factor—similar environment. The remarkable fact is that, as one proceeds northward from the New Mexico collecting area, he encounters vertebrates in southeastern Utah that are also present in north-central Texas but not in the intervening region, specifically, *Ectosteorhachis*, *Diplocaulus*, *Seymouria*, and *Dimetrodon*. This demands explanation, and I think the answer lies in the fact that southeastern Utah and north-central Texas were alike in Early Permian time in that they were both deltaic regions. The north-central New Mexico and southwestern Colorado faunas lived near the southwestern flank of the Uncompahgre-San Luis highland, relatively far removed from the persistent seaways of the time. Because all of these faunas lived in basins of sedimentation, it is difficult to draw a contrast between “lowlands” and “uplands” forms, but perhaps it may be said that the north-central New Mexico and southwestern Colorado faunas do represent *somewhat* more upland conditions.

Further collection and study will undoubtedly modify these conclusions. The suggestion that the southwestern Colorado fauna is to some degree intermediate between those of southeastern Utah and north-central New Mexico seems particularly worthy of further attention. The north-central Texas area has been searched for such a long time that it seems unlikely that, for example, *Sphenacodon* will be found there, but this is far from certain; such a find would modify the detailed analysis but would only support the main thesis developed here. Contrariwise, discovery in north-central New Mexico of any of the genera *Ectosteorhachis*, *Diplocaulus*, *Seymouria*, or *Dimetrodon* would

seriously weaken the thesis. In the meantime, the explanations offered may be regarded as a working hypothesis.

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